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APPLICATION AND EVALUATION OF WATER QUALITY POLLUTION INDICES FOR HEAVY METAL CONTAMINATION AS A MONITORING TOOL IN SHATT AL ARAB RIVER

MOHAMMAD S. MOYEL[1]
ALI H. AMTEGHY[2]
WESAL F. HASSAN[3]
ENAS A. MAHDI[4]
HUSSEIN H. KHALAF[5]

[1,2,3,4,5] Dept. of Marine Environmental Chemistry and Pollution-Marine Science Centre-Basrah University, Iraq

ABSTRACT

The objective of this study was to evaluate the applicability of two pollution indices namely: heavy metals pollution index (HPI) and Metal Pollution index (MPI) as a simple tools to investigate the degree of heavy metal pollution in Shatt Al Arab River. The indices values showed same trend with the high significant correlation also the indices values gave convincing results for the level of heavy metal contamination when comparing between the measured values of the metals with the Iraqi standards for drinking water. Accordingly, these indices can be used as a tool to evaluate heavy metal pollution of Shatt Al Arab River. Shatt Al Arab River waters was found critically and seriously polluted with heavy metals according to the indices. Statistically, significant correlations for Pb, Cd and Ni and the two indices which suggest strong and significant anthropogenic pollution source of Shatt Al Arab River. The study demonstrates a highly ecological system by anthropogenic sources.

KEY WORDS*:* Shatt Al Arab River, Water Quality Pollution Indices, Metals Contamination.

INTRODUCTION

Shatt Al Arab Riveris the main source of surface water in Basrah province, which has been used for various purposes including domestic water supply, irrigation, fisheries, navigation, and industrial uses (Husain *et al*., 1991 and Moyel 2014). Recently, there has been an increasing awareness of the river contamination with different pollutants in particular in pesticides, hydrocarbons and heavy metals. Therefore, monitoring and assessment of the river water pollution has become a very critical area of study because of direct influences of water pollution on the aquatic life and the human beings (Manoj *et al*., 2012 and Abdulla, 2013). Heavy metals are some some/one of the main source of toxicity problems in the aquatic environment when they occur above the threshold concentrations. Heavy metals can accumulate in the human body throughout the food web which can cause serious health problems (Lee *et al*., 2007 and Reza and Singh, 2010).The aquatic environment has been polluted by effluent wastes containing metals, from different activities, industrial and domestic effluents, agricultural runoff as well as inputs from atmosphere. One of the most crucial properties of these metals, which differentiate them from other toxic pollutants, is that they are not easily biodegradable in the environment (Rauret *et al.,* 1999andNasrabadi, 2015). The need for monitoring water quality on a regular basis has terminated in lots of studies run to develop, apply and evaluate index methods for water quality assessment (Horton, 1965; Nishidia *et al.,* 1982 and Prasad& Bose, 2001).Quality indices are a useful tools and relatively easy method to evaluate the composite influence of overall pollution. The quality indices are aimed to supply a useful and comprehensible guiding tool for water quality executives, decision makers, environmental managers, and potential users of a given water system (Bhuiyan *et al.,* 2010).Several numerical water quality indices were recently developed to provide interpretative tools for assessing metals pollution. The most used approaches are heavy metals pollution index (HPI) and Metal Pollution index (MPI).The present study aimed to evaluates the applicability of two pollution indices using some heavy metals. In addition, investigate the degree of heavy metal pollution using these indices.

Material and Methods

Study area and sampling sites

The confluence of Tigris and Euphrates Rivers at the Qurna town, north of Basra city to form the Shatt Al-Arab River, which is being a south-east direction to hurt in the Arabian Gulf (Table 1, Fig. 1). The Shatt Al-Arab River has a length of 200 km, a width range between 400 m at Basra and up to more than 2 km at the estuary and a depth of between 8-15 m, considering tides (Abdulla, 1990).

Shatt Al-Arab basin affected by hydrological conditions of the upper basins of the Tigris and Euphrates Rivers and tides of the Arabian Gulf, as well as the impact of climatic conditions prevailing in the region in discharge rates and payload River, since the area studied conditions characterized by irregular and access to water quantity and quality nutrition to control the conditions of rain-fed and groundwater from the Tigris and Euphrates Rivers and marshes water emerging from the Shatt al-Arab River (Al Mahmood, 2009).

Table 1. Sampling locations and coordinates of sampling stations at Shatt Al-Arab River

Station number	Station name	Longitude	Latitude
St. 1	Garma	47° 45 32. 39	30° 37 29.85
St. 2	Sindbad	47° 47 15.01	30° 33 59.12
St. 3	Ashar	47° 51 29.10	30° 30 12.43
St. 4	Mohela	47° 55 34.73	30° 28 .5.53
St. 5	Abuflouse	48°02 16.81	30° 27 37.77
St. 6	Seba	48° 16 36.48	30° 19 52.41
St. 7	Fao	48° 27 52.75	29° 59 23.73

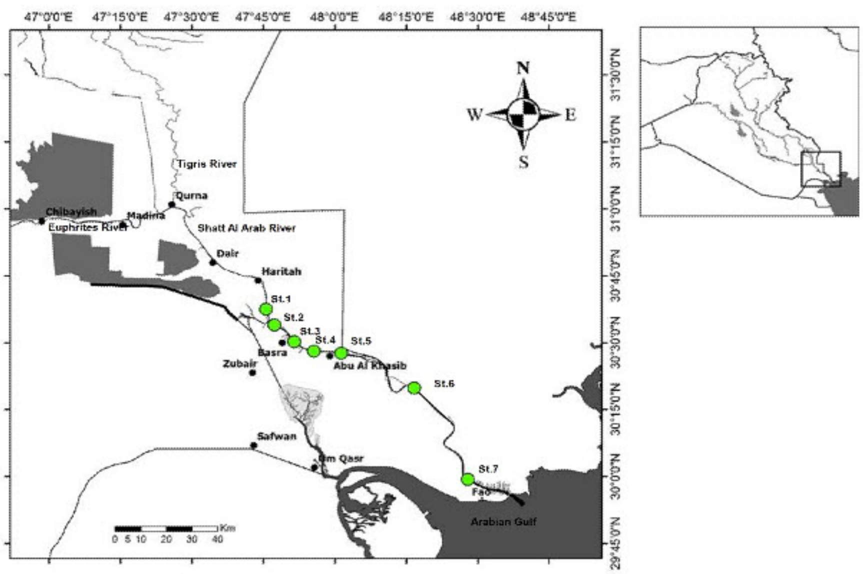

Figure 1. Map of Shatt Al-Arab River showing the seven sampling stations

Field Sampling and procedures

Sampling took place on a monthly basis from seven stations along Shatt Al-Arab River from December 2012 to November 2013. Physical and chemical parameters including water temperature (WT), electrical conductivity (EC), Dissolved oxygen (DO) and pH were measured *insitu* using the WTW Multi-meter model 4330. Sampling and analysis of water samples for heavy metals were conducted based on the standard methods as a described in APHA (2005).Water samples were collected from the river using 1000 ml polyethylene bottles, and preserved with HNO_3 and keep by refrigeration at a temperature of 4 ◦C until analysis. In this study, the samples were analyzed for heavy metals (Fe, Mn, Zn, Cd, Pb and Ni),using atomic absorption spectrophotometer (PG: AA500)with a specific lamp for each metal.

Water pollution indices

In this study, two documented indices were employed:

Heavy metal pollution index (HPI):

The HPI was proposed by Prasad and Bose (2001) which represent the total quality of water with respect to heavy metals. The HPI is calculated based on weighted arithmetic quality mean method and established in three steps: the calculation of weight age of ith parameter, second, the calculation of the quality rating for each of the heavy metal and third, the summation of these sub-indices in the overall index. The rating system is an arbitrarily value between zero to one, points the importance of the of individual quality considerations in a comparative way or it can be assessed by making values inversely proportional to the recommended standard for the corresponding parameter (Horton, 1965; Mohan *et al.*, 1996).

The weight age of i^{th} parameter is:

$Wi = k / Si$,

Where, Wi is the unit weight age and Si the recommended standard for ith parameter (i = 1-5), k is the constant of proportionality.

Individual quality rating is given by the expression:

$Qi = 100\ Vi / Si$,

Where, Qi is the sub index of ith parameter, Vi is the monitored value of the ith parameter in μg/L and Si the standard or permissible limit for the ith parameter.

The HPI is determined using the expression below:

$HPI = \Sigma\ WiQi / \Sigma Wi$,

Where, Qi is the sub index of ith parameter. Wi is the unit weight age for ith parameter, n is the number of parameters considered. Generally, the critical pollution index of HPI value for drinking water is 100(Prasad& Bose, 2001).

Metal Pollution Index (MPI)

Metal Pollution index (MPI) is defined as a method of rating that shows the composite influence of individual parameter son the overall quality of water (Reza and Singh, 2010).The rating is a value between zero and one, reflecting the relative importance of individual quality considerations. The higher the concentration of a metal compared to its maximum allowable concentration, the worse the water quality (Amadi, 2011).The MPI calculated as a described below:

MPI=Σ Ci/ MAC,

where: Ci: mean concentration of i^{th} parameter.

MAC: maximum allowable concentration.

Table 2. Water Quality Classification using MPI (Lyulko *et al*., 2001; Caerio *et al*., 2005).

Class	Characteristics	MPI
I	Very pure	<0.3
II	Pure	0.3-1.0
III	Slightly affected	1.0-2.0
IV	Moderately affected	2.0-4.0
V	Strongly affected	4.0-6.0
VI	Seriously affected	>6.0

In order to calculate the two indices of the water, the mean concentration value of the selected metals have been taken into account.

In this study, the Si and MAC values was taken from the Iraqi standard for drinking water No.417, 2009.

Results and discussion

The descriptive statistics of physicochemical parameters and total metal concentrations including the Iraqi standard for drinking water are given in Table3.The statistical analysis showed significant variations in the metals concentration along the course of the river except for Fe and Pb (Table 2).The mean concentrations of Fe, Cd, Pb and Ni were much higher than the Iraqi standards for drinking water. Whereas, the mean concentrations of the Mn and Zn were found to be below the Iraq standards at all of the studied stations (Table3).

The current study showed that the metal concentration distribution pattern between sampling stations are follows the decreasing order: (St.1)Fe > Pb > Ni >Zn> Mn >Cd, (St.2)Fe > Pb > Ni > Cd> Zn>Mn, (St.3)Pb> Fe > Ni > Zn> Cd>Mn, (St.4)Pb> Fe > Ni > Zn> Mn> Cd, (St.5)Fe > Pb > Zn >Ni > Mn >Cd, (St.6)Fe > Pb > Ni > Zn >Mn >Cd and (St.7) Pb> Fe > Ni > Zn> Cd> Mn, it is clear that Iron and Lead are the most dominant element of these metals in the water, where as zinc, nickel, Manganese and cadmium have a lower concentration. The high level of metals in the water may be attributed to the release from the deposits mineralization input.

HPI and MPI were calculated separately for each sampling stations to compare the pollution load of the selected stations (Figure 2).The HPI values for all stations were found to be far above the critical value of 100, this indicate that the Shatt Al Arab River is critically polluted with respect to heavy metals. This could be attributed to high concentrations of Fe, Cd, Pb and Ni which exceeded the highest permissible value of Iraqi standards for drinking water (Table 2). Generally, the highest HPI value (4731.19) was found at station 7, while the lowest value (793.90) was recorded at station 5(Figure 2).

The results of the MPI for all stations were found to be far above the highly score which suggested by Lyulko *et al*., (2001) and Caerio *et al*., (2005),suggests that the river is seriously affected with respect to heavy metal pollution(Figure2). However, the MPI and HEI show similar trends at the most sampling stations and the final classification gave two extreme results (Figure 2). The highest MPI value (199.24) was observed at station 7, and the lowest value (32.76) was recorded at station 5.

The result of the current study was in agreement with Al Hejuje (2014) who found that the Shatt Al Arab River was polluted with heavy metals by using HPI. Whereas, Abdullah (2013)found that the Shatt Al Arab River was unpolluted with heavy metals by using HPI and MPI, these results were disagreement with our study, this different results may attributed to short study period (one sample only during July, 2012) which couldn't give a clear picture about the river pollution status.

Table 3. Descriptive statistics for physicochemical parameters, total metal concentrations and the Iraqi standard for drinking water (*Si*).

Station	Statistic	WT (ºC)	pH	EC (mS/cm)	Cd (µg/L)	Fe (µg/L)	Pb (µg/L)	Mn (µg/L)	Zn (µg/L)	Ni (µg/L)
Garma	Mean	24.02	8.10	2.44	33.54	2893.73	819.14	40.78	62.07	89.79
	SD	5.00	0.16	0.78	39.37	3594.32	333.76	43.53	17.68	38.02
Sindbad	Mean	23.93	7.97	3.88	55.50	1394.55	1023.92	25.63	52.75	79.64
	SD	5.88	0.26	2.26	68.30	1085.58	255.98	13.97	23.78	27.98
Ashar	Mean	23.28	7.79	4.92	40.13	1605.47	1828.43	21.36	67.42	80.68
	SD	5.16	0.25	2.76	39.60	1425.95	2953.69	14.40	36.38	59.87
Mohela	Mean	23.01	7.81	5.39	26.87	1088.49	511.96	36.19	78.41	79.82
	SD	5.19	0.27	2.37	21.49	1014.33	232.12	15.97	43.36	55.46
Abuflouse	Mean	22.7	8.00	5.15	19.72	1869.68	853.27	31.45	85.45	83.29
	SD	5.32	0.13	1.90	7.79	1973.69	391.02	16.77	64.34	58.43
Seba	Mean	23.53	7.98	7.44	31.91	1814.14	921.53	38.57	79.07	144.01
	SD	5.24	0.19	7.88	22.81	2280.49	530.81	33.11	42.34	138.09

Faw	Mean	23.81	8.04	24.15	76.38	2337.52	2706.07	48.06	100.63	301.39
	SD	5.21	0.21	14.94	42.02	2320.20	2363.98	32.74	71.09	225.46
Total	Mean	23.48	7.96	7.62	41.23	1868.05	1502.85	34.45	76.08	123.30
	SD	5.12	0.23	9.43	41.91	2119.63	1877.27	27.35	47.95	130.32
LSD (P=0.05)		0.74	0.18	8.48	36.25	NS	NS	27.7	47.88	157.35
Si		-	-	-	3	300	10	100	3000	20

NS: Non-Significant.

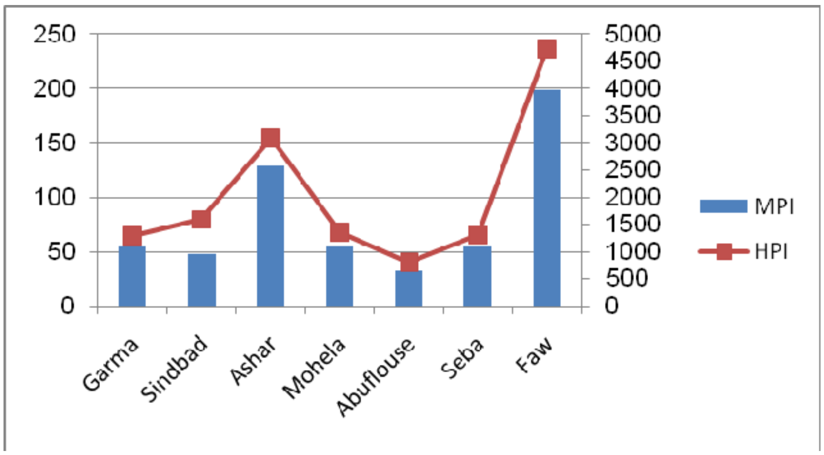

Figure 2. HPI and MPI values at various sampling stations.

Correlation coefficient and cluster analysis (CA) were performed between the indices results and heavy metal concentrations to investigate the key metals contributing to the computed indices. Correlation analysis showed very strong and significant correlations among the values of HPI and MPI for all the samples (Table 3).Also, a comparison between the indices and heavy metal concentration show significant correlation with Cd, Pb and Ni(Table 3). This indicates that these metals are the main contributory parameters, and the high correlation between these metals may indicate same source of pollutants. These metals come mainly from industrial effluents, through untreated domestic sewage discharges, traffic sources, land washout and boats activities and atmospheric depositions also contribute to it (Manoj *et al.,* 2012).Also, a significant correlation between Mn and Ni was observed. The rest of metals show no significant correlation with each other.

Hierarchical agglomerative CA was performed on the normalized data set using Ward's method with squared Euclidean distances as a measure of similarity. CA was used to group the analyzed metals and quality indices.CA rendered a dendrogram (Figure 3) where all six metals and quality indices were grouped into four statistically significant clusters. Cluster 1 showed significantly correlated between Pb, Cd and Ni with the two indices (Figure

3). In general, correlations between these metals with the two indices agreed with the results obtained by correlation coefficient.

Table3. Pearson's correlation coefficient for metal concentrations and indices values.

Variables	HPI	HEI	Cd	Fe	Pb	Mn	Zn	Ni
HPI	**1**							
HEI	**0.994**	**1**						
Cd	**0.840**	**0.785**	**1**					
Fe	0.483	0.514	0.483	**1**				
Pb	**0.985**	**0.996**	**0.755**	0.477	**1**			
Mn	0.432	0.468	0.464	0.745	0.479	**1**		
Zn	0.424	0.454	0.181	-0.083	0.517	0.400	**1**	
Ni	**0.809**	**0.816**	**0.772**	0.526	**0.837**	**0.773**	0.568	**1**

Values in bold are different from 0 with a significance level alpha=0.05

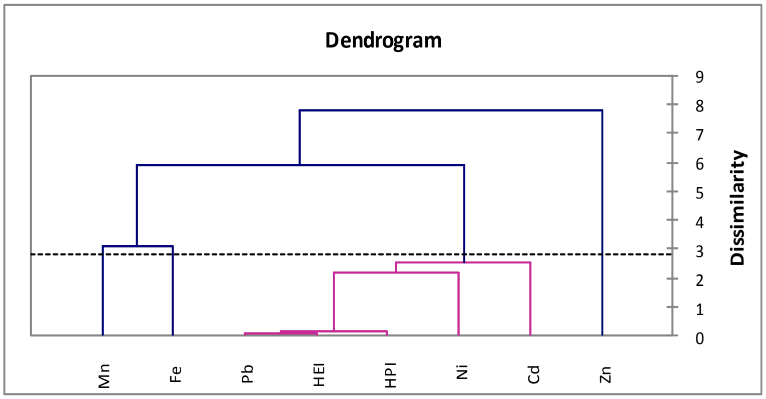

Figure 3. Dendrogram showing clustering of the analyzed metals and quality indices.

Conclusion

The quality of Shatt Al Arab River has been evaluated using two indices (HPI and MPI) based on the mean concentrations of the selected heavy metals. Values of the indices showed same trend and highly significant correlation using data from the study area. Accordingly, these indices can be used as a tool to evaluate heavy metal pollution of the Shatt Al Arab River. Shatt Al Arab River waters was found critically and seriously polluted with heavy metals according to these indices. Statistically, significant correlations for Pb, Cd and Ni and the two indices which suggest strong and significant anthropogenic pollution source of Shatt Al Arab River. The study demonstrates a highly ecological system by anthropogenic sources.

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